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(56) Documents Cited
GB 2235214 A GB 2234989 A GB 2012671 A
US 5141775 A
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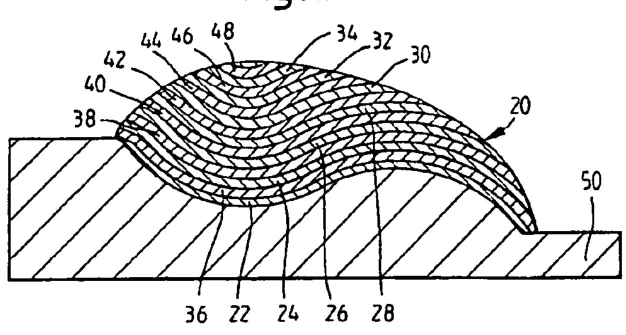
(54) **A method of manufacturing a fibre reinforced composite component**

(57) A fibre reinforced composite component, eg. a gas turbine blade is manufactured by stacking layers (22, 24, 26, 28, 30, 32, 34) of woven, eg. silicon carbide, fibres alternately with layers (36, 38, 40, 42, 44, 46, 48) of chopped, eg. silicon carbide, fibres compressing the stack (20) to the required thickness and applying a matrix eg. of silicon carbide by chemical vapour deposition. The stack may first be impregnated with polymeric resin binder to form a fibre preform. The silicon carbide deposits on the chopped fibres between the woven layers producing a denser, more uniform structure having better mechanical properties. Carbon may be used instead of silicon carbide both for the fibres and the matrix.

*Fig. 2*

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1

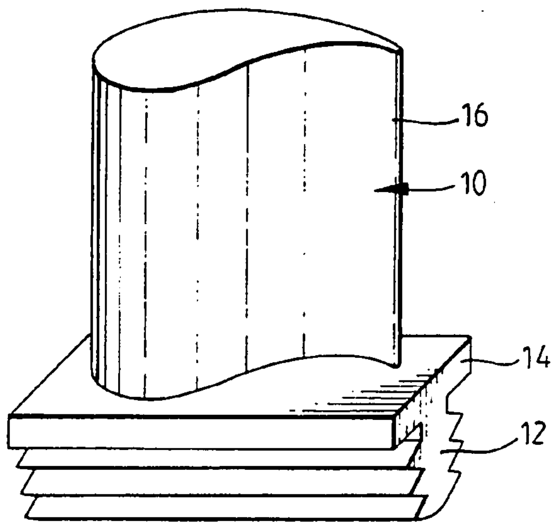
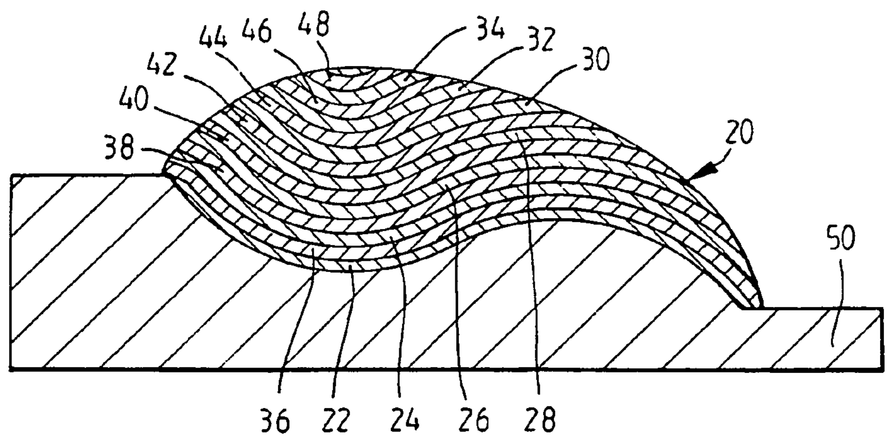



Fig.2



# A METHOD OF MANUFACTURING A FIBRE REINFORCED COMPOSITE COMPONENT

The present invention relates to a method of manufacturing fibre reinforced composite components, particularly silicon carbide fibre reinforced silicon carbide matrix composite components for gas turbine engines.

Silicon carbide fibre reinforced silicon carbide matrix composite components are known in the prior art. These components are produced by weaving the silicon carbide fibres into the required pattern and required shape to form a fibre preform. The silicon carbide matrix is then deposited onto the fibre preform by chemical vapour infiltration.

The fibre preform is impregnated with a polymeric resin binder and the fibre preform is located in a graphite mould during the chemical vapour infiltration. The graphite mould is required to support the fibre preform during the chemical infiltration process because the polymeric resin binder burns out of the fibre preform, during the heating up process for the chemical vapour infiltration, leaving just the fibres which cannot support themselves.

The fibres are generally woven into a fibre preform suitable for the shape of the component being produced. The fibres may be one dimensionally, two dimensionally or three dimensionally woven. The simplest and cheapest method is to weave the fibres into a two dimensional tape, which is then stacked in layers and compressed to obtain the required thickness of material.

A problem with the silicon carbide fibre reinforced silicon carbide matrix composite components produced by this method is that the infiltration of the silicon carbide between the individual layers of woven fibres is poor, resulting in large residual voidage and hence poor mechanical properties. The reason for this is that it is difficult to achieve intimate contact between the layers

of woven fibres. The total thickness of silicon carbide deposited during the chemical vapour infiltration process is typically around 20 x $10^{-6}$ m and, therefore any voids greater than twice this dimension remain as voids after the manufacturing process. The voids in between the layers of woven fibres may be several millimetres in dimension, and hence will not be filled by chemical vapour infiltration. It has been observed that frequently the individual layers of woven fibres are only in contact at a small number of points and it is this which is responsible for the relatively poor mechanical properties of the composite component.

The present invention seeks to provide a novel method of manufacturing fibre reinforced composite components which at least reduces, or overcomes, the above mentioned problems.

Accordingly the present invention provides a method of manufacturing a fibre reinforced composite component comprising the steps of

(a) arranging a plurality of layers of woven fibres alternately with layers of chopped fibres to form a preform,

(b) and depositing a matrix material onto the alternate layers of woven fibres and chopped fibres of the preform by chemical vapour infiltration to form a fibre reinforced composite component.

Preferably the method comprises weaving the fibres into a two dimensional tape, cutting the tape into pieces and stacking the pieces of tape alternately with the layers of chopped fibres to form the preform.

The method may comprise weaving the fibres into a two dimensional tape, folding the tape and arranging layers of chopped fibres between the folds of the tape to form the preform.

Preferably the chopped fibres are arranged in a suitable binder. Preferably the fibres are impregnated with a polymeric resin to form the preform. Preferably

the matrix material is deposited onto the fibres at high temperature and low pressure conditions. Preferably the matrix material is silicon carbide and the fibres are silicon carbide fibres. The silicon carbide matrix may be deposited by pyrolysis of methyltrichlorosilane.

The component may be a turbine blade or a turbine vane.

The present invention will be more fully described by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of a silicon carbide fibre reinforced silicon carbide matrix turbine blade,

Figure 2 is a cross-sectional view through a preform at one stage of the manufacturing process.

A silicon carbide composite gas turbine engine blade 10, as shown in figure 1, comprises a root portion 12, a platform portion 14 and an aerofoil portion 16.

The silicon carbide composite turbine blade 10 is manufactured by weaving a first set of silicon carbide fibres into a predetermined pattern and a required shape, to define the exterior shape of the component. The silicon carbide fibres are typically Nicalon, Registered Trade Mark, or Tyranno, Registered Trade Mark. The silicon carbide fibres are generally woven into a two dimensional tape. The two dimensional tape is then cut into a plurality of separate pieces of woven silicon carbide fibres of appropriate length for the component being produced. A second set of silicon carbide fibres are cut into short lengths to produce chopped silicon carbide fibres.

The plurality of separate pieces of woven silicon carbide fibres are stacked alternately with the chopped silicon carbide fibres to produce a stack 20 comprising alternate layers 22, 24, 26, 28, 30, 32 and 34 of woven silicon carbide fibres and layers chopped 36, 38, 40, 42, 44, 46 and 48 of silicon carbide fibres as shown in figure 2. The silicon carbide fibres are approximately

40 volume % of the finished component, although other suitable volume fractions may be used. The stack 20 is then compressed to obtain the required thickness of material. The chopped silicon carbide fibres move under the pressure of the layers of woven silicon carbide fibres to bridge the large, interlaminar voids between the layers of woven silicon carbide fibres.

The silicon carbide fibres in the stack 20 are impregnated with a polymeric resin binder to form a fibre preform.

The fibre preform is arranged on a graphite mould 50 which supports the silicon carbide fibres during the subsequent chemical vapour infiltration process.

The fibre preform is then processed in the conventional manner to deposit the silicon carbide onto the silicon carbide fibres to produce the silicon carbide matrix. The fibre preform and graphite mould are positioned within a vacuum chamber, which is evacuated to a suitably low pressure. The temperature in the vacuum chamber is increased to a suitably high temperature for the chemical vapour infiltration process, for example a temperature of 1000°C to 1100°C is suitable. At this temperature the polymeric resin binders on the fibres is evaporated and extracted from the vacuum chamber. A suitable gaseous precursor is then introduced into the vacuum chamber and silicon carbide is deposited onto the silicon carbide fibres by pyrolysis to form a silicon carbide fibre reinforced silicon carbide matrix composite component. In the pyrolysis process the fibre preform is heated in an atmosphere of hydrogen which has a low concentration of methyltrichlorosilane. The methyltrichorosilane diffuses into the fibre preform and undergoes thermal decomposition in the reducing hydrogen atmosphere to deposit silicon carbide onto the silicon carbide fibres. Hence the silicon carbide matrix is built up around the individual silicon carbide fibres in the layers of woven silicon carbide fibres and around the

individual silicon carbide fibres in the layers of chopped silicon carbide fibres. The silicon carbide matrix is deposited to a thickness of $10 - 40 \times 10^{-6}$m, typically $20 \times 10^{-6}$m.

The effect of the layers of chopped silicon carbide fibres between the layers of woven silicon carbide fibres is to provide additional surfaces upon which the silicon carbide deposits. The silicon carbide, therefore deposits on the chopped silicon carbide fibres between the layers of woven silicon carbide fibres and this results in a denser, more uniform structure which also has a larger effective contact area between the individual layers of woven silicon carbide fibres, hence increasing the mechanical properties of the SiC/SiC composite, particularly the interlaminar properties.

As an alternative to cutting the two dimensional tape into a plurality of separate pieces, it is possible to fold the tape over on itself a plurality of times and to arrange layers of chopped silicon carbide fibres between adjacent folds of the tape to produce a stack comprising alternate layers of woven silicon carbide fibres.

The layers of woven silicon carbide may be of any suitable type and may be three dimensional weaves.

It is preferred that the layers of chopped silicon carbide fibres are layers of chopped fibres in a binder, polymeric resin or thermosetting resin. The chopped fibres are mixed with a polymeric resin or thermosetting resin, in the molten liquid state. The mixture of chopped fibres and resin is pressurised and directed through a nozzle to produce an elongate tape, which subsequently solidifies. The tape of chopped fibres and resin is then cut at appropriate lengths. The advantage of using the tapes of chopped fibres and resin is that it is handleable and it produces a uniform distribution of chopped fibres.

Alternatively it may be possible to place layers of chopped fibres directly onto layers of woven fibres by scattering the chopped fibres thereon.

Although the invention has referred to silicon carbide fibres in a silicon carbide matrix, it may be possible to apply the same principle to other fibres in other matrixes, provided the matrix material is deposited by chemical vapour infiltration, for example carbon fibres and a carbon matrix.

Claims:-

1. A method of manufacturing a fibre reinforced composite component comprising the steps of:

(a) arranging a plurality of layers of woven fibres alternately with layers of chopped fibres to form a preform,

(b) and depositing a matrix material onto the alternate layers of woven fibres and chopped fibres of the preform by chemical vapour infiltration to form a fibre reinforced matrix component.

2. A method as claimed in claim 1 comprising weaving the fibres into a two dimensional tape, cutting the tape into pieces and stacking the pieces of tape alternately with the layers of chopped fibres to form the preform.

3. A method as claimed in claim 1 or claim 2 comprising arranging the chopped fibres in a suitable binder.

4. A method as claimed in claim 1, claim 2 or claim 3 comprising impregnating the fibres with a polymeric resin to form the preform.

5. A method as claimed in any of claims 1 to 4 comprising depositing the matrix material onto the fibres at high temperature and low pressure conditions.

6. A method as claimed in any of claims 1 to 5 wherein the fibres are silicon carbide fibres.

7. A method as claimed in any of claims 1 to 6 wherein the matrix material is silicon carbide.

8. A method as claimed in claim 7 wherein the silicon carbide is deposited by pyrolysis of methyltrichlorosilane.

9. A method of manufacturing a fibre reinforced composite component substantially as hereinbefore described with reference to the accompanying drawings.

10. A fibre reinforced composite component as made by the method of any of claims 1 to 9.

11. A fibre reinforced composite component as claimed in claim 10 in which the component is a turbine blade or a turbine vane.

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| **Patents Act 1977**<br>**Examiner's report to the Comptroller under Section 17**<br>**'The Search report)** | Application number<br>GB 9320696.9 |
| **Relevant Technical Fields**<br>(i) UK Cl (Ed.L) B5A (AA2); C7F (FHB, FHE, FHX); D1R (RAA, RABB, RABX, RDC, RDE, RFA, RFZ)<br>(ii) Int Cl (Ed.5) C04B; C23C | Search Examiner<br>ALEX LITTLEJOHN<br><br>Date of completion of Search<br>22 DECEMBER 1993 |
| Databases (see below)<br>(i) UK Patent Office collections of GB, EP, WO and US patent specifications.<br><br>(ii) ONLINE DATABASES: WPI | Documents considered relevant following a search in respect of Claims :-<br>1-11 |

**Categories of documents**

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document

| Category | Identity of document and relevant passages | | Relevant to claim(s) |
|---|---|---|---|
| Y | GB 2235214 A | (UNITED TECHNOLOGIES) - see especially page 4 lines 31, 32 | 8 |
| X, Y | GB 2234989 A | (DUNLOP) - see whole document , eg page 2 lines 2-7 and 31 | X: 1, 2, 10<br>Y: 5-8 |
| X, Y | GB 2012671 A | (DUNLOP) - see whole document, eg page 1 lines 34-36 and page 2 lines 30-52 | X: 1, 2, 10<br>Y: 5-8 |
| X, Y | US 5141775 | (PATRIGEON) - see whole document, eg column 2 line 50 - column 3 line 53 | X: 1, 2, 5-7, 10<br>Y: 5-8 |
| X, Y | WPI Abstract Accession No: 90-198826/26 & JP 2133373 (SHOWA) 22.05.90 (see abstract) | | X: 1, 2, 10<br>Y: 5-8 |

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).